Chapter 1

Introduction

1.1. BACKGROUND

Section 7(a) of Public Law 97-414 directs the Secretary of Health and Human Services to "(1) conduct scientific research and prepare analyses necessary to develop valid and credible assessments of the risks of thyroid cancer that are associated with thyroid doses of Iodine 131; (2) conduct scientific research and prepare analyses necessary to develop valid and credible methods to estimate the thyroid doses of Iodine 131 that are received by individuals from nuclear bomb fallout; and (3) conduct scientific research and prepare analyses necessary to develop valid and credible assessments of the exposure to Iodine 131 that the American people received from the Nevada atmospheric nuclear bomb tests; ..."

The National Cancer Institute (NCI) was requested to respond to this mandate. This report describes the data, methodologies, and analyses that were used to address parts (2) and (3) of the mandate. The report does not address the issue of the risk of thyroid cancer associated with thyroid doses of iodine-131. Efforts to estimate this risk have been and continue to be the objective of a number of past and ongoing studies of persons exposed to iodine-131 from diagnostic procedures or from environmental contamination in Utah, in the Hanford, Washington area, in Sweden, Slovenia and Israel, and in Belarus, the Russian Federation and Ukraine.

A task group, established to assist the NCI in this effort, suggested that it might be possible to estimate, for each atmospheric nuclear weapons test, the iodine-131 (^{131}I or I-131) exposures from fallout for representative individuals and for the populations of each county of the contiguous U.S. In this report, "Nevada atmospheric bomb tests" is interpreted as meaning "tests conducted at the Nevada Test Site that released radioactive materials into the atmosphere," thus including also cratering tests and underground tests which vented, or released radioactive materials into the atmosphere, as well as the tests that were part of a peaceful applications program. All such tests were considered.

The most significant atmospheric weapons tests with respect to fallout occurred in the 1950s, during which time most of the monitoring of environmental radioactivity consisted of gross beta measurements. Because the radioactive half-life of ^{131}I is about 8 days, the activity of ^{131}I present in the samples collected more than 35 years ago has completely decayed and cannot be measured retrospectively. Therefore, the estimation of ^{131}I exposures dating back to the 1950s must essentially be derived either from the original measurements of gross beta activity, from current or past measurements of radionuclides other than ^{131}I, or from mathematical models.

1.2. METHODOLOGY

Previous studies have suggested that once ^{131}I from fallout has been deposited on vegetation the main exposure route to man is, for individuals who drink milk, the ^{131}I transported from the vegetation to cows consuming the vegetation to the milk produced by the cows to man via the consumption of milk, i.e., via the pasture-cow-milk food chain (Bergström 1967; Eisenbud and Wrenn 1963; Garner and Russell 1966; UNSCEAR 1972). This is due to a combination of factors: (a) cows graze over large areas of ground, (b) the population regularly consumes substantial amounts of fresh cows' milk, and (c) there is a short delay time between the production and consumption of milk.

However, exposures resulting from inhalation of contaminated air or the ingestion of foodstuffs other than cows' milk may be more important than those resulting from ingestion of cows' milk for people who drink little or no cows' milk or for people who drink milk from cows that were not on pasture. This report will focus on the assessment of doses of radiation to the thyroid of people resulting from the consumption of milk produced by cows grazing on pasture contaminated with ^{131}I from fallout and will discuss inhalation of contaminated air and the ingestion of foodstuffs other than cows' milk in much less detail. *Figure 1.1* illustrates the various steps involved in the dose assessment.

When absorbed into the body, ^{131}I concentrates in the thyroid to such an extent that the radiation absorbed doses in other organs and tissues are negligible in comparison. For a given intake of ^{131}I, the radiation absorbed doses in the thyroid of people vary as a function of age, the highest doses being received by infants. In this report, thyroid doses are calculated for various age categories (i.e., fetus, infant, child, adult male and female).

For each atmospheric test, radiation absorbed doses to the thyroids of people have been estimated for the population of each county subdivided by age and sex, assuming average, high, and low exposure to ^{131}I. Collective thyroid doses also have been calculated for the entire population of each county *(Figure 1.2)* and for the entire population of the contiguous United

Figure 1.1. Steps involved in the assessment of the exposure to I-131 that the American people received from the atmospheric bomb tests (simplified diagram).

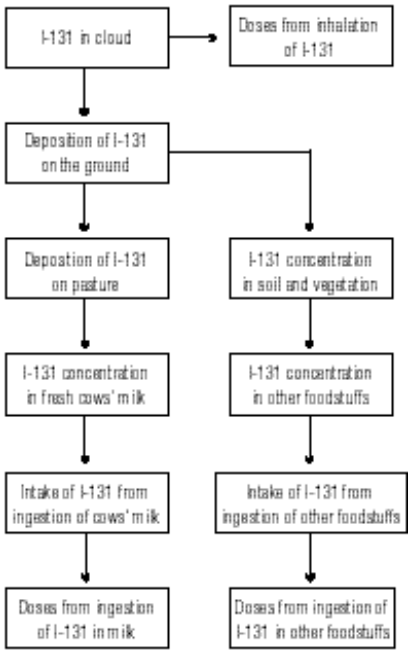
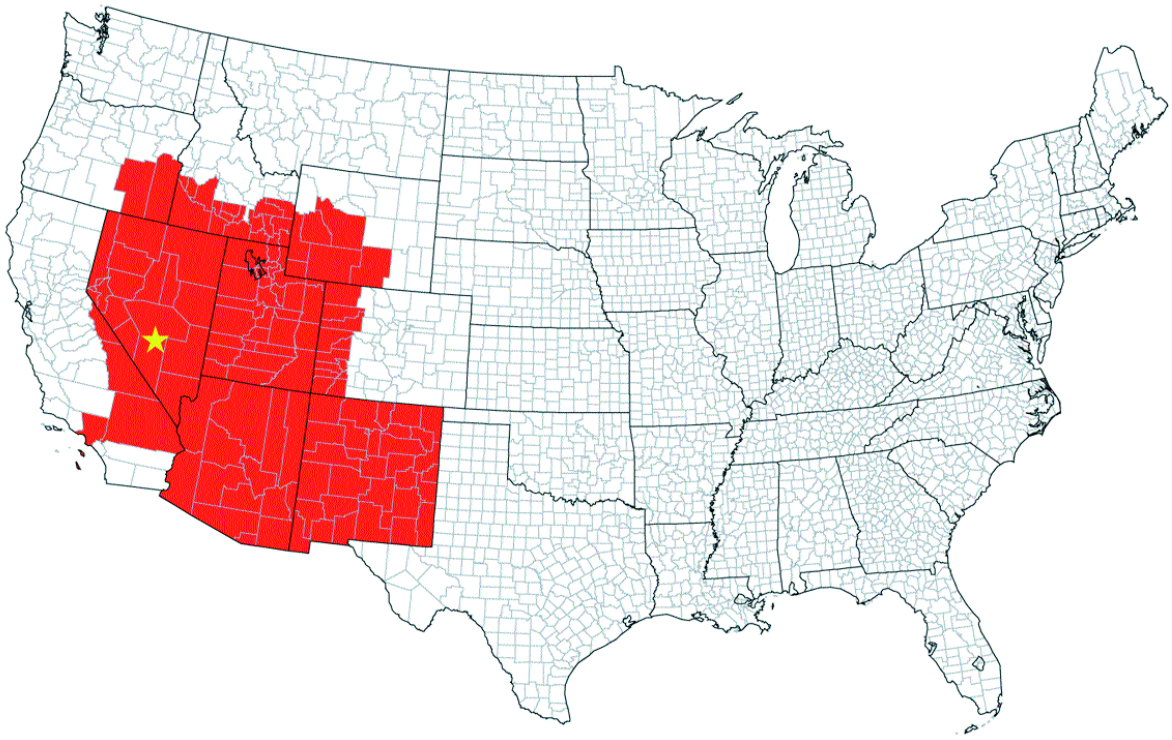


Figure 1.2. County boundaries of the contiguous United States. The area in red represents the geographical coverage of the Offsite Radiation Exposure Review Project (ORERP) study. The location of the Nevada test site is marked with a yellow star within the area in red.



States following each test. Appendices and Annexes to the report present results in sufficient detail so that an individual can estimate his/her own thyroid dose given his/her residential history and dietary habits. Estimates of the uncertainties associated with the dose values and with the principal parameters entering into the dose calculations also are provided.

In addition to the present study, two other studies address the exposure of more specific populations to ^{131}I from fallout. The Offsite Radiation Exposure Review Project (ORERP) of the Department of Energy (Church et al. 1990) estimated exposures of downwind residents of several states to fallout *(Figure 1.2)* with special emphasis on the residents of four counties in Nevada (Clark, Esmeralda, Lincoln, and Nye) and of Washington County in Utah. The University of Utah reported on an epidemiological study of thyroid disease among identified populations of Utah and Nevada, together with retrospective estimates of individual thyroid doses due to ^{131}I in fallout (Kerber et al. 1993; Lloyd et al. 1990; Till et al. 1995).

The environmental transfer models used in the three studies to estimate the extent to which individuals or populations were exposed to ^{131}I are similar. There are some differences that distinguish this study from the other two, however, because of its larger geographic scope. The data and parameter values (e.g., dietary patterns, lifestyle) used in this study represent averages and are not specific to individuals or to limited population groups as in the other two studies. Also, because most of the deposition of radioactive materials on the ground in the eastern part of the country was associated with precipitation (i.e., "wet" deposition), whereas "dry" deposition (i.e., deposition of radioactive materials on the ground that was not associated with precipitation) was predominant in the western part of the country (Beck et al. 1990), the effect of precipitation on the fallout has received a greater emphasis in this study than was required for the other two studies.

It is important to note that the internal radiation absorbed doses in the thyroid of people from ^{131}I in NTS fallout that are calculated in this report constitute only one component of the thyroid doses that the American people received in the 1950s. Internal irradiation of the thyroid resulted also from the intake of ^{131}I from other sources (e.g., nuclear weapons testing at sites other than the NTS, whether by the United States or by other countries, atmospheric discharges from weapons producing facilities such as nuclear reactors and fuel reprocessing plants, medical uses of ^{131}I and, to a lesser extent, from the intake of radionuclides other than ^{131}I (e.g., ^{133}I or ^{132}I)). In addition, thyroid doses were also received as a result of external irradiation from the Nevada Test Site (NTS) fallout and from other sources, including natural background. A rough indication of the relative magnitude of the contributions to the thyroid dose from all those sources is provided in the report.

1.3. ORGANIZATION OF THE REPORT

This report includes:

- The history of nuclear weapons testing at the Nevada Test Site **(Chapter 2).**
- The deposition of ^{131}I on the ground **(Chapter 3).**
- The transfer of ^{131}I from deposition on the ground to fresh cows' milk **(Chapter 4).**
- The production, utilization, distribution, and consumption of milk across the continental U.S. **(Chapter 5).**
- The methods and data used to calculate radiation absorbed doses in the thyroids of people resulting from the ingestion of fresh cows' milk **(Chapter 6).**
- The methods and data used to calculate radiation absorbed doses in the thyroids of people resulting from exposure routes to people other than the ingestion of fresh cows' milk **(Chapter 7).**
- The results, expressed in terms or per capita of collective radiation absorbed doses in the thyroids of people **(Chapter 8).**
- How to calculate an individual's thyroid absorbed dose **(Chapter 9).**
- Model validation and the uncertainties attached to the estimates of radiation absorbed dose in the thyroids of people **(Chapter 10).**

The main body of the text is supplemented with Appendices and Annexes. The Appendices present detailed information on some aspects of the methodology used and general data that are not related to any specific nuclear test:

- The meteorological dispersion and deposition model that was used to predict estimates of ^{131}I deposition per unit area of ground when environmental radiation data were not available **(Appendix 1)**.
- The structural characteristics of the methodology used in the dose assessment, as well as the origin and content of the databases **(Appendix 2)**. Special consideration is given to the data related to the counties close to the Nevada Test Site because of the complexity of fallout deposition patterns in that area.

- Information on pasture practices **(Appendix 3).**
- The estimated volumes of milk annually produced, available for fluid use and consumed in each county of the contiguous United States in 1954 **(Appendix 4).**
- Information on regional milk distribution **(Appendix 5).**
- A review of the metabolism and dosimetry of ^{131}I **(Appendix 6).**
- The influence on the resulting thyroid doses of the distribution of physico-chemical forms of ^{131}I in fallout **(Appendix 7).**
- The initial retention of fallout ^{131}I by vegetation according to distance from the NTS and to daily rainfall **(Appendix 8).**
- Information on the main computer codes used in the dose assessment **(Appendix 9).**

The basic information and the main results obtained for each nuclear test that is taken into consideration in the dose assessment are presented as Annexes and as Sub-annexes.

The Annex for a given nuclear test includes:

- A description of the test along with a presentation of the environmental data, specific for that test, that have been used in the dose assessment.
- A color-coded map showing estimates of ^{131}I depositions per unit area of ground for all counties of the contiguous United States.
- Tabulated estimates of ^{131}I concentrations in fresh cows' milk resulting from the test for each county of the contiguous United States.
- Tabulated estimates of ^{131}I concentrations in ground-level air and in foodstuffs other than fresh cows' milk, resulting from the test, for each county of the contiguous United States.
- A color-coded map showing estimated thyroid-dose ranges for all counties of the contiguous United States.

In addition, results are summarized in the Annexes for each test series (corresponding, in many cases, to one year of testing) either in the form of tables or of maps. The tabulated results, in particular, enable an individual to obtain an approximate estimate of her (or his) own individual thyroid dose, provided that the individual considered knows, among other factors, her (or his) consumption rate of milk and the geographical origin of that milk during the time period of the test series. The results provided in the Annexes for each test series and for each county of the contiguous United States are:

- Tabulated estimates of ^{131}I concentrations in fresh cows' milk.
- Tabulated estimates of ^{131}I concentrations in ground-level air and in foodstuffs other than fresh cows' milk.
- Tabulated estimates of radiation absorbed doses in the thyroid of people to several categories of people in each age class that are expected to represent a reasonable spectrum of the population.
- Maps presenting estimates of ^{131}I depositions per unit area of ground and of "per capita" radiation absorbed doses in the thyroids of people resulting from the test series.

There is a Sub-annex for each nuclear weapons test. Each Sub-annex consists of:

- Tables showing the estimated daily ^{131}I depositions per unit area of ground for each county of the U.S. following each test.
- Tables presenting, for each county following each test:

  Estimates of the collective thyroid dose and the per capita thyroid dose to the county population.

  Estimates of the thyroid doses to each age group (and gender for the adult population) for each of the four milk consumption scenarios considered.

REFERENCES

Beck, H. L.; Helfer, I. K.; Bouville, A.; Dreicer, M. Estimates of fallout in the continental U.S. from Nevada weapons testing based on gummed-film monitoring data. Health Phys. 59: 565-576; 1990.

Bergström, S. O. W. Transport of fallout ^{131}I into milk. Pages 159-174 in Radiological Concentration Processes (Aberg, B, and F. P. Hungate, eds.). Pergamon Press, 1967.

Church, B. W.; Wheeler, D. L.; Campbell, C. M.; Nutley, R. V. Overview of the Department of Energy's Offsite Radiation Exposure Review Project (ORERP). Health Phys. 59: 503-510 ; 1990.

Eisenbud, M.; Wrenn, M. E. Biological disposition of radioiodine - A review. Health Phys. 9:1133-1139; 1963.

Garner, R. J.; Russell, R. S. Isotopes of iodine. Pages 297-315 in: Radioactivity and Human Diet (Russell, R. S., ed.). New York: Pergamon Press Ltd.; 1966.

Kerber, R. A.; Till, J. E. ; Simon, S. L. ; Lyon, J. L. ; Thomas, J. C. ; Preston-Martin, S, ; Rallison, M. L. ; Lloyd, R. D. ; Stevens, W. A cohort study of thyroid disease in relation to fallout from nuclear weapons testing. JAMA 270:2076-2082; 1993.

Lloyd, R. D.; Simon, S. L.; Till, J. E. Development of an algorithm to estimate dose from fallout radioiodine to persons in a thyroid cohort. Health Phys. 59: 669-691; 1990.

Till, J.E.; Simon, S.L.; Kerber, R.; Lloyd, R.D.; Stevens, W.; Thomas, D.C.; Lyon, J.L.; Preston-Martin, S. The Utah thyroid cohort study: Analysis of the dosimetry results. Health Phys. 68: 460-471; 1995.

UNSCEAR. Ionizing Radiation: Levels and Effects. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly, with Annexes. United Nations sales publication No. E.72.IX.17 and 18. New York, 1972.